# Investigation of Resident Fishes in Tustumena Lake, Kenai National Wildlife Refuge, Alaska, 1987

Ray N. Jones
and
Dave Faurot

Kenai Fishery Assistance Office
P.O. Box 1670
Kenai, Alaska 99611

December 1991

Investigation of Resident Fishes in Tustumena Lake,
Kenai National Wildlife Refuge, Alaska, 1987

DISCLAIMER

The mention of a trade name or commercial product does not constitute recommendation for use by the Federal Government.

The correct citation for this report is:

Jones, R.N. and D.A. Faurot. 1991. Investigation of resident fishes in Tustumena Lake, Kenai National Wildlife Refuge, Alaska, 1987. U.S. Fish and Wildlife Service, Alaska Fisheries Technical Report Number 14, Kenai, Alaska.

## ABSTRACT

Gill nets and minnow traps were used to determine the relative abundance of resident fish at three locations in Tustumena Lake, Alaska, during the spring and summer of 1987. The food habits, length-weight relationships, relative condition, age structure, and growth rates of selected species were also examined.

Dolly Varden *Salvelinus malma* and lake trout *S. namaycush* were the most frequently caught species in gill nets. Dolly Varden and coastrange sculpins *Cottus aleuticus* were most frequently caught in minnow traps. The highest catches for all species except rainbow trout *Oncorhynchus mykiss* were consistently taken at Bear Creek.

Lake trout and Dolly Varden had quite dissimilar food habits. Lake trout stomachs contained mostly fish (90%) while Dolly Varden stomachs contained mostly invertebrates (80%). Insects were the most commonly found invertebrates in lake trout and Dolly Varden stomachs.

Fork lengths of lake trout ranged from 275-560 mm. Fork lengths of Dolly Varden ranged from 62-572 mm. Fork lengths of round whitefish *Prosopium cylindraceum* ranged from 172 to 375 mm. All three species had allometric growth. Ages of lake trout ranged from 4 to 26. Ages of Dolly Varden ranged from 1 to 13. Ages of round whitefish ranged from 3 to 11. Growth rates and condition factors of lake trout and Dolly Varden varied widely with age.

Consistently higher catches of resident fish at Bear Creek indicate higher productivity at this site than at Clear or Nikolai creeks. Since Bear Creek is one of two sites where sockeye salmon *O. nerka* fry are stocked in Tustumena Lake, higher productivity in this area may be due to enhancement activities.

TABLE OF CONTENTS

## LIST OF TABLES



## LIST OF FIGURES

## LIST OF APPENDICES

## INTRODUCTION

Since 1976, the Alaska Department of Fish and Game (Department) has been stocking sockeye salmon *Oncorhynchus nerka* fry into Tustumena Lake in an effort to augment natural production. Approximately 88 million fingerlings were stocked from 1978 to 1984 (Flagg et al. 1986). Concern has been expressed that this activity may be having a significant impact on resident fish populations. For example, interspecific interactions between sockeye salmon fry and important sport fish species, such as lake trout *Salvelinus namaycush* and Dolly Varden *S. malma*, could be occurring.

Tustumena Lake supports a variety of resident fish species including round whitefish *Prosopium cylindraceum*, rainbow trout *O. mykiss*, Dolly Varden, lake trout, threespine stickleback *Gasterosteus aculeatus*, coastrange sculpin *Cottus aleuticus*, and slimy sculpin *C. cognatus* (U.S. Fish and Wildlife Service, unpublished data). Lake trout and Dolly Varden were collected by the Department at several locations in Tustumena Lake as part of a limnological investigation to determine whether these two species were preying on sockeye salmon fry (Litchfield 1981). No other data on the resident fish populations in Tustumena Lake are available.

Since there are no data on resident fish populations dating before the sockeye salmon stocking program was initiated, direct assessment of the possible impacts on resident fish populations is impossible. However, by establishing the present condition and status of resident fish populations in Tustumena Lake, comparisons can be made with populations in other glacial lakes, and a relative determination of impact might be possible. At the very least, collection of baseline population data on resident fish in Tustumena Lake will provide a basis for possible future assessments and other management purposes.

This study had the following objectives:

1. To estimate the relative abundance of resident fish species;
2. To examine the food habits of lake trout and Dolly Varden;
3. To examine the length-weight relationships and relative condition of lake trout, Dolly Varden, and round whitefish; and,
4. To examine the age structure and growth rates of lake trout, Dolly Varden, and round whitefish.

## STUDY AREA

Tustumena Lake is located in the western portion of the Kenai National Wildlife Refuge about 22.5 km south of Soldotna, Alaska. The lake, the largest lake on the Kenai Peninsula, is approximately 40 km long, 8 km wide, and is 33 m above mean sea level. Tustumena Lake has a surface area of about 29,450 hectares, a volume of about 36,583 cubic hectares, a maximum depth of 290 m, and a mean depth of 124 m. The drainage basin is approximately 259,000 hectares and has its origins in the Harding Icefield, making the lake highly glacial (Litchfield 1981). Seasonal (May-October) mean turbidity varies from 39 to 46 Nephelometric Turbidity Units. Seasonal (May-October) mean lake water temperatures vary from 6.3 to 9.8°C at 1 m deep.

## METHODS

A stratified sampling design was employed by dividing Tustumena Lake into three major areas (A, B, and C) corresponding to the sampling design established by the Department (Litchfield 1981). Field activities were initiated on April 20 and consisted of preliminary sampling with experimental gill nets and minnow traps at various locations throughout the lake with the intention of selecting one permanent sampling location in each major area. Three of these locations, the mouths of Bear Creek, Clear Creek, and Nikolai Creek were selected as permanent sampling locations for all subsequent data collection (Figure 1). Shantatalik Creek and the lake outlet locations were rejected because of the low numbers of lake trout caught. Indian Creek was rejected because the shoreline dropped off so steeply that setting gill nets was extremely difficult.

### *Relative Abundance*

Fish were collected using experimental monofilament gill nets and minnow traps. The gill nets were 30.4 m long, 2.8 m deep, and had five 6 m panels of 25 mm, 51 mm, 63 mm, 76 mm, and 102 mm stretched mesh. The minnow traps were 43 cm long, 23 cm in diameter, consisted of 6 mm mesh galvanized wire, and were baited with salmon eggs.

In April and May, three gill nets were set at each permanent sampling location. A floating gill net was set in shallow habitat, 2-3 m deep near shore, and adjacent to the stream mouth. Another floating gill net was set at the water surface, in deep habitat (20-30 m) offshore, and a sinking gill net was set in the same area on the lake bottom. Gill nets were set perpendicular to the shoreline with the smallest mesh closest to shore. In June, only the sinking gill nets were set. Gill nets were not used during the rest of the investigation to avoid capturing large numbers of returning adult sockeye salmon.

In April, May, and June, six minnow traps were set at each permanent sampling location. Four traps were set in shallow water <1 m deep immediately adjacent to the shoreline and two traps were set in water 20-30 m deep. In July, 8-10 minnow traps were set out at each permanent sampling location. All were placed in shallow water <1 m deep immediately adjacent to the shoreline.

Gill nets and minnow traps were securely anchored with concrete weights and marked with floating buoys. Gill nets and minnow traps were left for approximately 24 hours and retrieved the next day in the same order they were set.

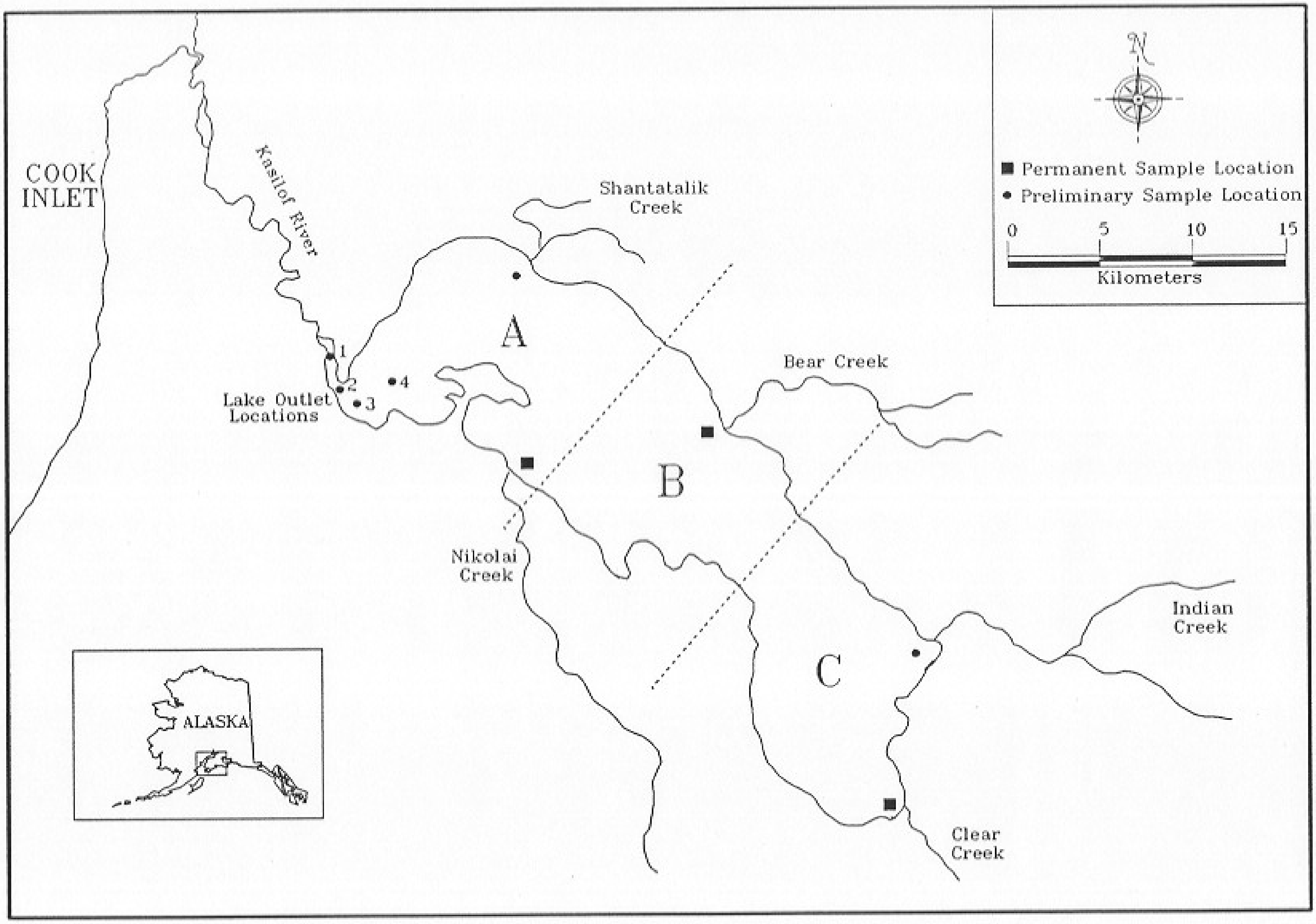


FIGURE 1.–Sampling locations on Tustumena Lake, Kenai National Wildlife Refuge, Alaska.

Gill-net and minnow-trap catches were examined separately to determine the relative abundance of resident fish species. Percent composition was used as an index to compare relative abundance of each species between sampling locations. Catch per unit effort was used to compare the relative abundance of resident fishes caught in minnow traps and was calculated by dividing the total catch for each species by the number of traps set.

*Food Habits*

Stomachs of lake trout and Dolly Varden were removed and stored in a 50% solution of isopropyl alcohol and water. Stomach contents were examined using a Bausch and Lomb dissecting microscope. Items found in the stomachs of lake trout and Dolly Varden were grouped under five major categories: unidentifiable material, fish, vegetation, fish eggs, and invertebrates. Insects were identified to order (Merrit and Cummins 1978), fish were identified to species (Morrow 1980) when possible, and other invertebrates were generally identified to major taxonomic groups (Barnes 1974; Pennak 1978).

Stomach samples collected during April, May, and June in sinking gill nets at Clear, Bear and Nikolai creeks were analyzed to evaluate the diets of lake trout and Dolly Varden. The frequency of occurrence of various food items was calculated by taking the number of stomachs that contained one or more of a given food item and expressing it as a percentage of the total number of non-empty stomachs (Windell and Bowen 1978).

*Length-Weight Relationships and Relative Condition*

Lake trout, Dolly Varden, rainbow trout, and round whitefish were measured to the nearest mm (fork length) and weighed to the nearest gram. Lake trout, Dolly Varden, rainbow trout, and round whitefish were sexed, or classified as immature if sex was not discernable.

Length frequency histograms were constructed for lake trout, Dolly Varden, and round whitefish using data collected at both the preliminary and permanent sampling locations. For Dolly Varden, data collected from both gill nets and minnow traps were used. Two mm intervals were used to more precisely detect age modes.

Length-weight relationships were developed for lake trout, Dolly Varden, and round whitefish using the allometric growth model

$$W = aL^b$$

where a and b are constants derived from regressing the logarithms (base 10) of weight (W) and fork length (L)(Anderson and Gutreuter 1983). Functional regressions and intercepts were estimated using the geometric mean regression technique (Ricker 1975). Data collected at both preliminary and permanent sampling locations were used. For Dolly Varden, data collected from both gill nets and minnow traps were used.

Relative condition (Ricker 1975) factors were calculated for lake trout, Dolly Varden, and round whitefish using data collected at both the preliminary and permanent sampling locations. For Dolly Varden, data collected from both gill nets and minnow traps were used. Relative condition was calculated using the formula:

$$Kn = \frac{W}{aL^b};$$

Kn = relative condition factor;
W = weight of fish in grams;
L = fork length in millimeters;
a = constant derived from length-weight regression;
b = constant derived from length-weight regression.

A two-sample t-test was used to compare mean condition factors of immature and adult Dolly Varden, immature and adult round whitefish, adult male and female lake trout, adult male and female Dolly Varden, and adult male and female round whitefish. An observed significance level of $P \leq 0.05$ was used to reject the null hypothesis that test groups did not have significantly different condition factors.

A one-way analysis of variance (ANOVA) was used to compare condition factors of adult male and female lake trout, Dolly Varden, and round whitefish at various ages. An observed significance level of $P \leq 0.05$ was used to reject the null hypothesis that condition factors were not significantly different between various ages of each test group.

*Age Structure and Growth Rates*

Techniques for aging varied by species. Ages of whitefish were determined by scale analysis. Scales of round whitefish were removed from the left side of the body, above the lateral line, and just below the dorsal fin (Ambrose 1983). Scales were pressed onto acetate sheets and examined on a microfiche reader to determine the number of annuli. Dolly Varden and lake trout ages were determined from sagittal otoliths which were stored dry in scale envelopes (Ambrose 1983) until they were mounted on glass slides for reading. Otoliths were examined whole under a dissecting microscope and ground with a dental drill as necessary to facilitate interpretation. Low level direct lighting was the primary viewing method, although varied lighting levels and reflected lighting were used in some cases. Wetting the surface of the otolith with a 50% ethanol solution improved optical distinction between the opaque and hyaline zones, while lessening the scratched appearance due to grinding.

Round whitefish growth rates were determined by measuring the projected image distance from the scale focus to each annuli along a straight line and back calculating fish length at age (Lagler 1956). Otoliths were not used to back calculate growth rates of Dolly Varden and lake trout due to difficulties in locating annuli on a consistent line from the nucleus to the anterior edge (Ambrose 1983). Instead, Dolly Varden and lake trout were grouped by age and mean length. The difference in mean lengths between consecutive age groups was calculated and used as a relative indicator of growth for comparison with other studies.

## RESULTS

Ten species of fish were collected (Table 1). Anadromous species included one rainbow trout (steelhead), the first evidence of this species in the lake. Dolly Varden, lake trout, and round whitefish were the most widely distributed species and chinook salmon *O. tshawytscha* and rainbow trout the least widely distributed. No pink salmon *O. gorbuscha* were captured in 1987 because runs to this area occur during even years.

### *Relative Abundance*

Of 633 resident fish captured in gill nets at permanent sampling locations, 398 or 63% of the total catch were Dolly Varden, 170 or 27% of the total catch were lake trout, and 60 or 9% of the total catch were round whitefish (Table 2). Resident rainbow trout were scarce (5 or <1%). Bear Creek consistently produced the highest catches of all species except rainbow trout. Sixty-six percent of the total catch was taken at Bear Creek, 26% at Nikolai Creek and 8% at Clear Creek. The species composition at each sampling location was quite similar to that of the total catch (Table 2).

Of the resident fish caught in minnow traps, coastrange sculpin and Dolly Varden had the highest catches per unit effort (Table 3). Catches were highest in shallow habitat. Only 15 fish, all coastrange sculpins, were collected from deep habitat. Catches of Dolly Varden and coastrange sculpins increased sharply in July. Only one slimy sculpin was collected. This species was taken in shallow habitat at Bear Creek.

### *Food Habits*

A total of 129 lake trout and 100 Dolly Varden stomachs was examined to describe the food habits of these two species. Both species had relatively high frequencies of occurrence (>.40) of empty stomachs during April and May and much lower frequencies of occurrence in June. Overall, Dolly Varden had a higher frequency of occurrence (.49) of empty stomachs than lake trout (.35)(Table 4).

Identifiable fish included threespine sticklebacks, sculpins, and sockeye salmon fry. The species of sculpin could not be determined. Unidentifiable fish were believed to include lake trout, Dolly Varden, and salmon. Invertebrates consisted primarily of aquatic insect larvae (Diptera, Plecoptera, Trichoptera, and Ephemerotera) and mollusks.

Lake trout and Dolly Varden had different diets. The diet of lake trout was dominated by fish (90%) and invertebrates (55%) while that of Dolly Varden was dominated by invertebrates (80%) and fish eggs

Table 1.–Fish species collected with gill nets and minnow traps in Tustumena Lake, Kenai National Wildlife Refuge, Alaska, 1987.

| Species | Locations: Lake outlet 1 | Lake outlet 2 | Lake outlet 3 | Lake outlet 4 | Shantatalik Creek | Indian Creek | Clear Creek | Nikolai Creek | Bear Creek | Total number of locations |
|---|---|---|---|---|---|---|---|---|---|---|
| Coho salmon | X | | X | | X | [a] | X | X | | 5 |
| Sockeye salmon | X | | | | | [a] | X | [a] | X | 3 |
| Chinook salmon | | | | | X | | | | | 1 |
| Round whitefish | X | X | X | | X | X | X | X | X | 8 |
| Rainbow trout | | | | | X | | | X | | 2 |
| Dolly Varden | X | X | X | X | X | X | X | X | X | 9 |
| Lake trout | X | X | X | X | X | X | X | X | X | 9 |
| Threespine stickleback | X | | | | X | X | X | [b] | [b] | 4 |
| Coastrange sculpin | X | | | | X | X | X | X | X | 6 |
| Slimy sculpin | X | | | | X | X | | | X | 5 |
| Total number of species | 8 | 3 | 4 | 2 | 9 | 6 | 7 | 7 | 7 | |

[a] Adults were visually observed at stream mouths in September and October.
[b] Threespine sticklebacks were collected in one of the two samples collected at Nikolai and Bear creeks during July. However, because lables for these two samples were inadvertantly lost, the species is not reported for either location.

TABLE 2.-Number of round whitefish (RW), rainbow trout (RB), Dolly Varden (DV), and lake trout (LT) collected with gill nets at each permanent sampling location in Tustumena Lake, Kenai National Wildlife Refuge, Alaska, 1987.

| Location | Month | Number of gill nets | Species RW | RB[a] | DV | LT | Total |
|---|---|---|---|---|---|---|---|
| Clear Creek | April | 3 | 3 | 0 | 6 | 5 | 14 |
| | May | 3 | 0 | 0 | 25 | 2 | 27 |
| | June | 1 | 0 | 0 | 9 | 3 | 12 |
| | Total | 7 | 3 | 0 | 40 | 0 | 53 |
| Nikolai Creek | April | 3 | 9 | 3 | 14 | 19 | 45 |
| | May | 3 | 9 | 1 | 75 | 19 | 104 |
| | June | 1 | 2 | 1 | 6 | 4 | 13 |
| | Total | 7 | 20 | 5 | 95 | 42 | 162 |
| Bear Creek | April | 3 | 10 | 0 | 69 | 60 | 139 |
| | May | 3 | 8 | 0 | 173 | 39 | 220 |
| | June | 1 | 19 | 0 | 21 | 19 | 59 |
| | Total | 7 | 37 | 0 | 263 | 118 | 418 |
| Total | April | 9 | 22 | 3 | 89 | 84 | 198 |
| | May | 9 | 17 | 1 | 273 | 60 | 351 |
| | June | 3 | 21 | 1 | 36 | 26 | 84 |
| | Total | 21 | 60 | 5 | 398 | 170 | 633 |

[a] Includes resident rainbow trout only. One additional anadromous rainbow trout (steelhead) was captured.

TABLE 3.-Catch per unit effort (CPUE [number/trap]) for Dolly Varden (DV), threespine stickleback (TS), coastrange sculpin (CS), and slimy sculpin (SS) collected with minnow traps in Tustumena Lake, Kenai National Wildlife Refuge, Alaska, 1987.

| Location | Month | Number of traps | Species DV | TS | CS | SS | CPUE total |
|---|---|---|---|---|---|---|---|
| Clear Creek | April | 6 | 0.3 | 0.0 | 2.5 | 0.0 | 2.5 |
| | May | 6 | 0.3 | 0.0 | 1.7 | 0.0 | 2.0 |
| | June | 6 | 0.0 | 0.7 | 5.8 | 0.0 | 6.7 |
| | July | 8 | 12.6 | 0.3 | 22.3 | 0.0 | 35.1 |
| | Total | 26 | 4.0 | 0.2 | 8.7 | 0.0 | 12.9 |
| Nikolai Creek | April | 6 | 0.2 | 0.0 | 1.5 | 0.0 | 1.7 |
| | May | [a] | | | | | |
| | June | 6 | 0.0 | 0.0 | 2.7 | 0.0 | 2.7 |
| | Total | 12 | 0.1 | 0.0 | 2.1 | 0.0 | 2.2 |
| Bear Creek | April | [a] | | | | | |
| | May | 6 | 0.2 | 0.0 | 1.0 | 0.0 | 1.2 |
| | June | 6 | 0.0 | 0.0 | 2.0 | 0.2 | 2.2 |
| | Total | 12 | 0.1 | 0.0 | 1.5 | 0.1 | 1.7 |
| [b]Nikolai and Bear Creeks | July | 20 | 4.6 | 0.2 | 13.8 | 0.0 | 18.5 |
| Total | April | 12 | 0.1 | 0.0 | 0.9 | 0.0 | 1.0 |
| | May | 12 | 0.3 | 0.0 | 1.3 | 0.0 | 1.6 |
| | June | 18 | 0.0 | 0.2 | 3.5 | 0.1 | 3.8 |
| | July | 28 | 6.9 | 0.2 | 16.2 | 0.0 | 23.3 |
| | Total | 70 | 2.8 | 0.1 | 7.8 | <0.1 | 10.9 |

[a] Traps lost or broken due to severe weather.
[b] Labels for Nikolai and Bear Creek samples were inadvertantly mixed so the two samples were combined.

TABLE 4.-Number (N) of stomachs containing major food items and the frequency of occurrence (Freq.) of those items for Dolly Varden and lake trout collected from Tustumena Lake, Kenai National Wildlife Refuge, Alaska, 1987.

| | April | | May | | June | | Total | |
|---|---|---|---|---|---|---|---|---|
| Fish/food items | N | Freq. | N | Freq. | N | Freq. | N | Freq. |
| Dolly Varden | | | | | | | | |
| Number of stomachs examined | 17 | | 47 | | 36 | | 100 | |
| Empty stomachs | 8 | 0.47 | 29 | 0.62 | 12 | 0.33 | 49 | 0.49 |
| Unidentifiable | 1 | 0.11 | 6 | 0.33 | 8 | 0.33 | 15 | 0.29 |
| Fish | 3 | 0.33 | 3 | 0.17 | 4 | 0.17 | 10 | 0.20 |
| Vegetation | 1 | 0.11 | 3 | 0.17 | 2 | 0.08 | 6 | 0.12 |
| Fish eggs | 7 | 0.77 | 16 | 0.89 | 1 | 0.04 | 24 | 0.47 |
| Invertebrates | 8 | 0.88 | 18 | 1.00 | 15 | 0.62 | 41 | 0.80 |
| Lake Trout | | | | | | | | |
| Number of stomachs examined | 64 | | 39 | | 26 | | 129 | |
| Empty stomachs | 26 | 0.41 | 16 | 0.41 | 4 | 0.15 | 46 | 0.35 |
| Unidentifiable | 3 | 0.08 | 2 | 0.09 | 0 | 0.00 | 5 | 0.06 |
| Fish | 33 | 0.87 | 21 | 0.91 | 21 | 0.95 | 75 | 0.90 |
| Vegetation | 4 | 0.10 | 0 | 0.00 | 0 | 0.00 | 4 | 0.05 |
| Fish eggs | 2 | 0.05 | 4 | 0.17 | 0 | 0.00 | 6 | 0.07 |
| Invertebrates | 19 | 0.50 | 16 | 0.69 | 11 | 0.50 | 46 | 0.55 |

(47%)(Table 4). For both species, the invertebrates were primarily insects.

Sockeye salmon fry did not appear to be a major component of the diet of either lake trout or Dolly Varden (11% and 10% overall, respectively). However, lake trout and Dolly Varden collected in the vicinity of the Department's sockeye salmon fry releases at Bear Creek in June had stomachs full of sockeye salmon fry.

*Length-Weight Relationships and Relative Condition*

Lake trout ranged from 275 to 560 mm fork length with lengths between 354 and 454 mm being the most frequent (Figure 2). Dolly Varden ranged from 62 to 572 mm fork length with lengths between 82 and 134 mm and between 264 and 444 mm being the most frequent (Figure 3). Round whitefish ranged from 172 to 375 mm fork length with lengths between 248 and 300 mm being the most frequent (Figure 4).

Length-weight relationships calculated for lake trout, Dolly Varden, and round whitefish revealed that all three species experience allometric growth with weight increasing at a faster rate than length (Figures 5, 6, and 7). Correlation coefficients ranged from 0.82 for round whitefish to 0.99 for Dolly Varden.

Relative condition factors were computed for 211 lake trout, 595 Dolly Varden, and 154 round whitefish. No significant differences were observed between immature and adult Dolly Varden or round whitefish. All lake trout collected were adults so no statistical comparison of immature and adult condition factors was possible. No significant differences in mean condition were observed between male and female lake trout or round whitefish. No significant differences in mean condition were observed between age groups for male and female lake trout and round whitefish. Mean condition factors for lake trout and round whitefish were 1.01 and 1.05, respectively. A significant difference ($P < .001$) in mean condition was observed between male and female Dolly Varden but no significant differences between age groups for either males or females were observed. Male and female Dolly Varden had mean condition factors of 1.04 and 0.98, respectively.

*Age Structure and Growth Rates*

Otoliths were used to age 188 lake trout. Ages ranged from 5 to 26 for males and from 4 to 21 for females. Mean length at age tended to be greater for females than males (Table 5). The oldest fish were not necessarily the longest fish. The longest lake trout, 560 mm, was 15 years old, while the oldest fish, 26 years, was 519 mm.

For the 411 Dolly Varden aged (Table 6), ages ranged from 1 to 13 years. At age 3, the population was 96% sexually immature but by age 5 only 8% were sexually immature. The most frequently caught Dolly Varden were 5 and 6 years old.

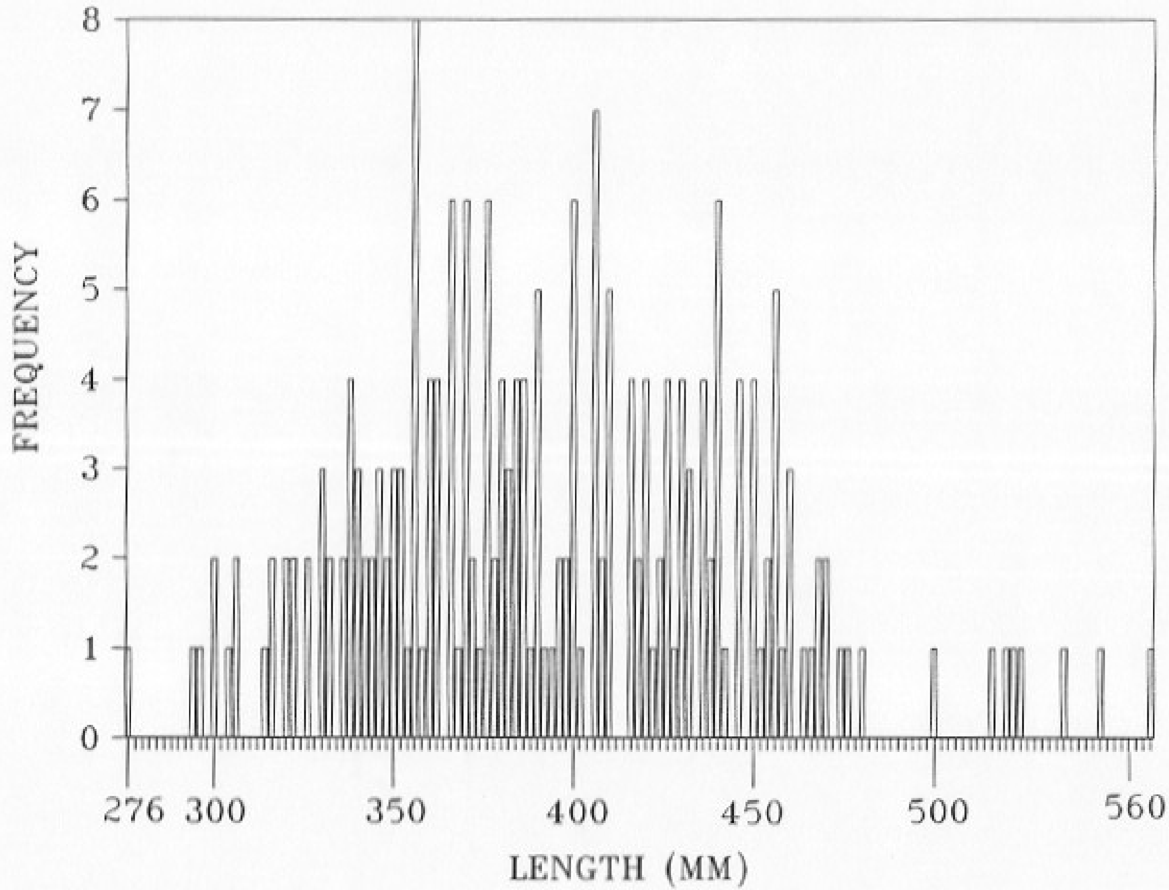


FIGURE 2.-Length frequency of lake trout collected from Tustumena Lake, Kenai National Wildlife Refuge, Alaska, 1987.

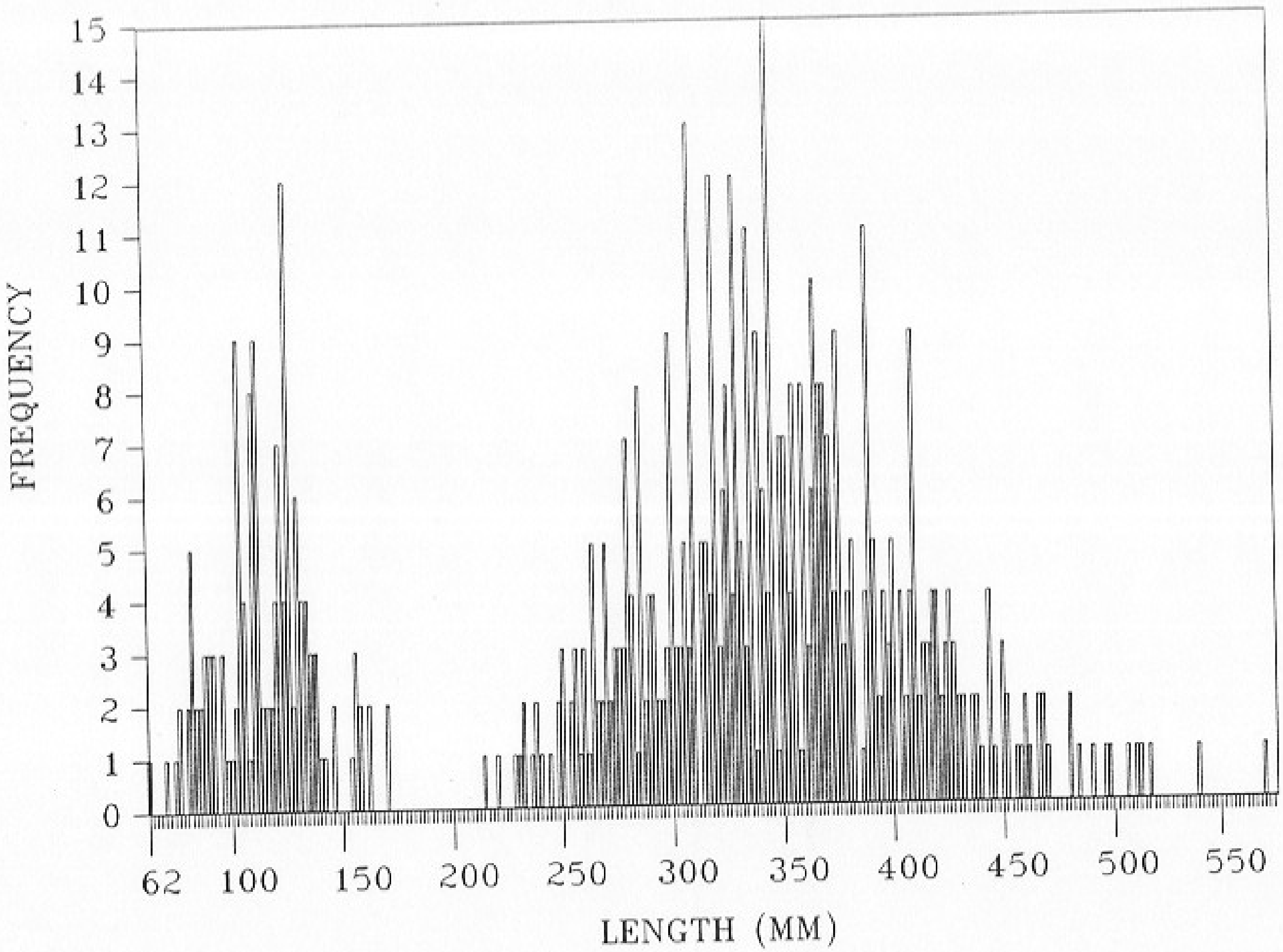


FIGURE 3.—Length frequency of Dolly Varden collected from Tustumena Lake, Kenai National Wildlife Refuge, Alaska, 1987.

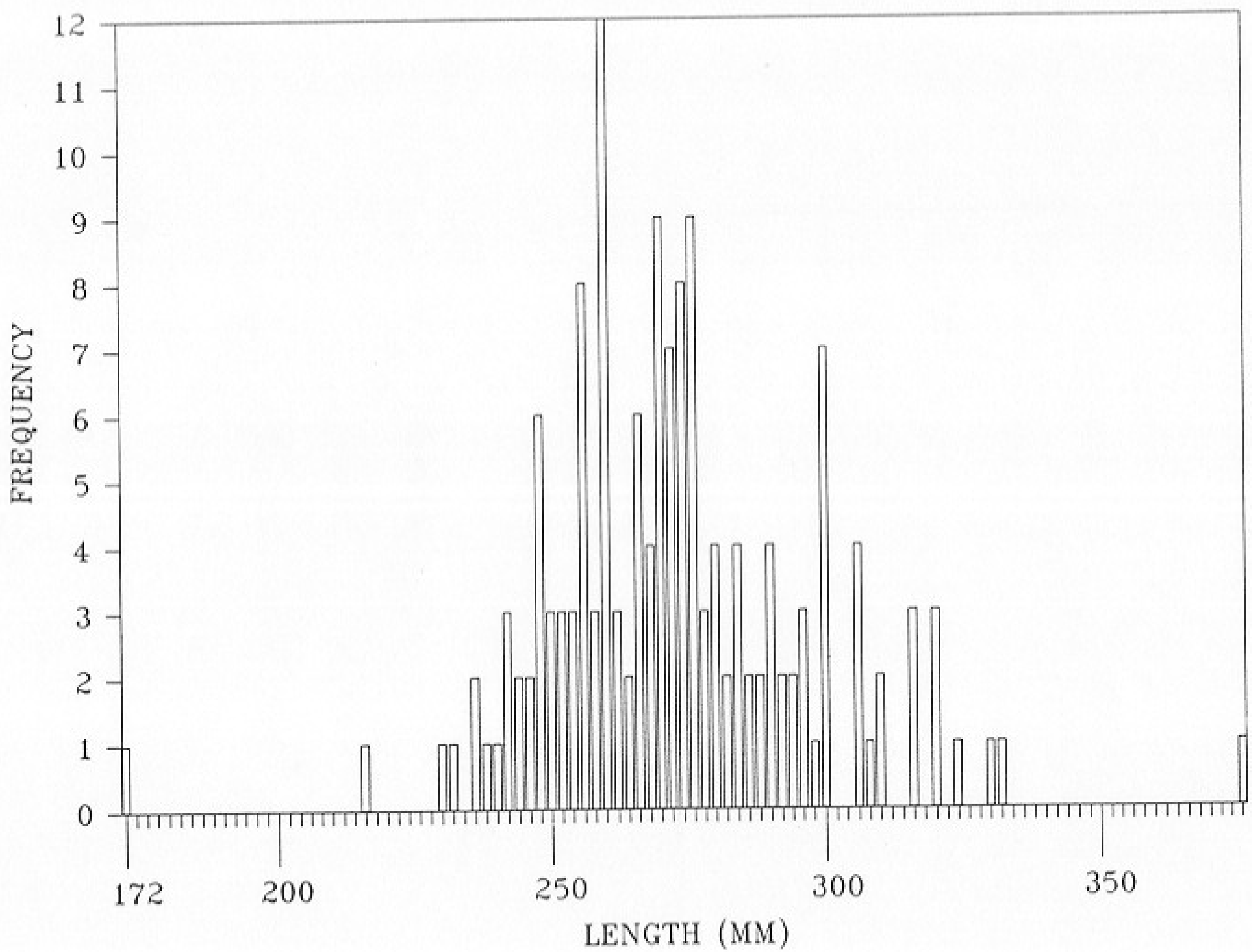


FIGURE 4.–Length frequency of round whitefish collected from Tustumena Lake, Kenai National Wildlife Refuge, 1987.

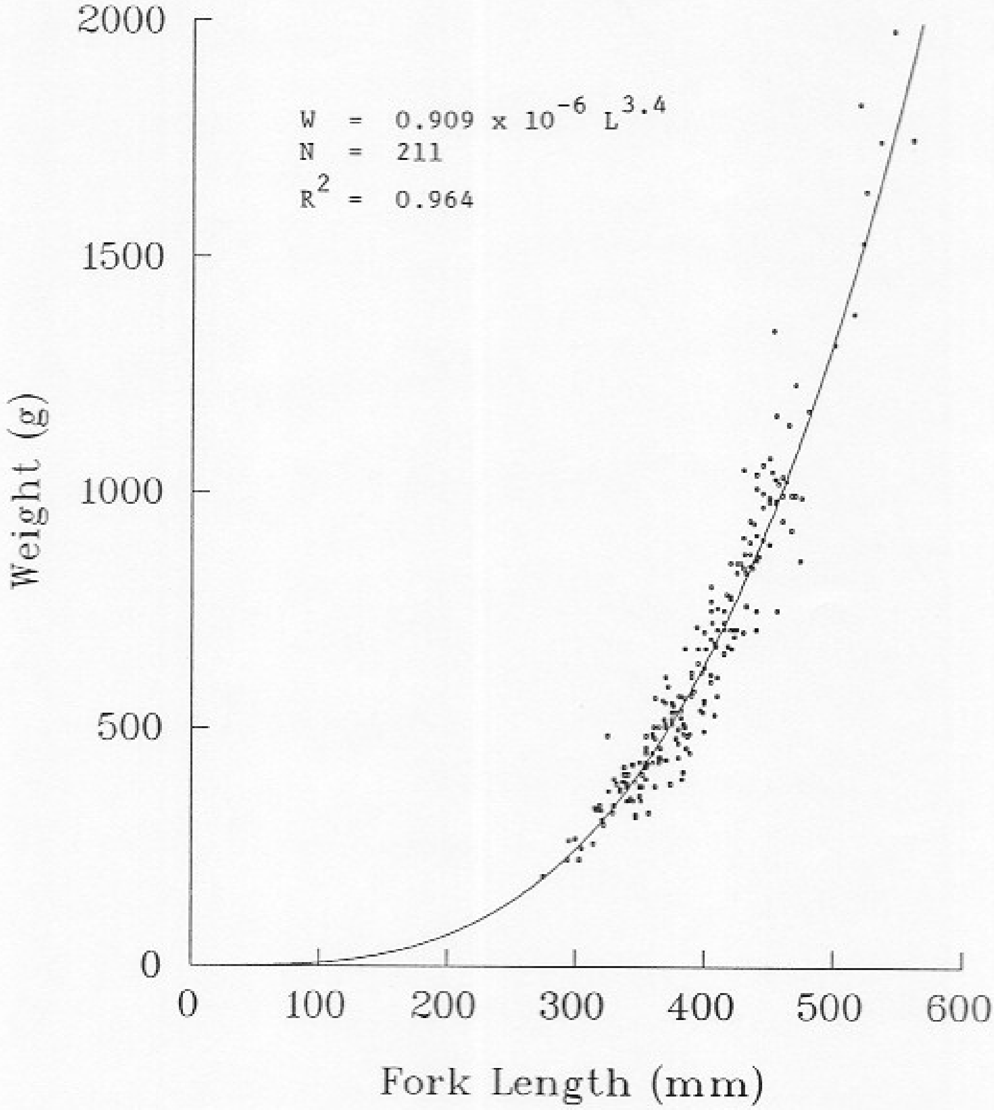


FIGURE 5.–Length-weight relationship for lake trout collected from Tustumena Lake, Kenai National Wildlife Refuge, Alaska, 1987.

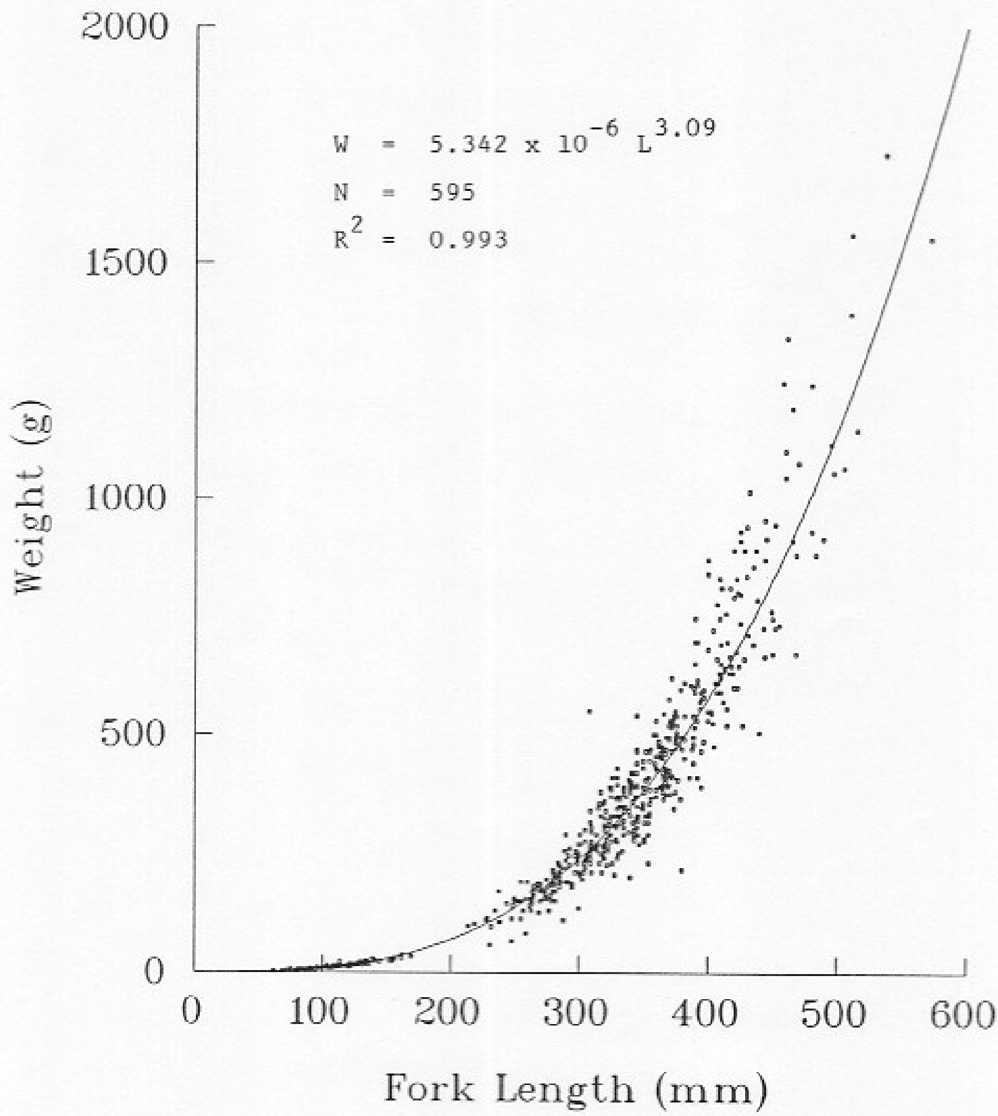


FIGURE 6.—Length-weight relationship for Dolly Varden collected from Tustumena Lake, Kenai National Wildlife Refuge, Alaska, 1987.

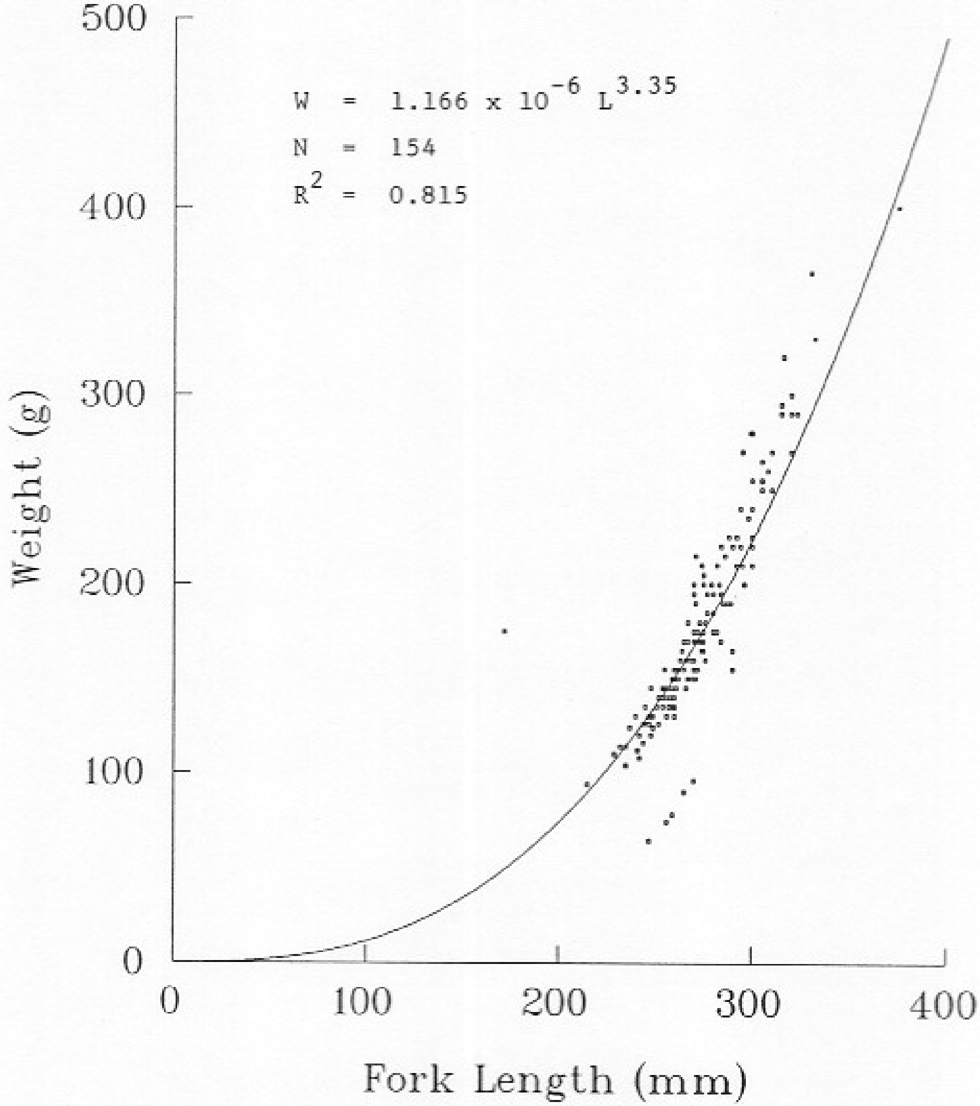


FIGURE 7.—Length-weight relationship for round whitefish collected from Tustumena Lake, Kenai National Wildlife Refuge, Alaska, 1987.

TABLE 5.-Lake trout mean lengths (mm) by age group, Tustumena Lake, Kenai National Wildlife Refuge, Alaska, 1987.

| | Male | | Female | | Total | | Relative growth increment |
|---|---|---|---|---|---|---|---|
| Age | Mean | N | Mean | N | Mean | N | |
| 4 | | 0 | 305 | 1 | 305 | 1 | |
| 5 | 299 | 2 | 354 | 2 | 332 | 5 | 27 |
| 6 | 322 | 5 | 344 | 1 | 326 | 6 | - 6 |
| 7 | 356 | 2 | 390 | 2 | 373 | 4 | 47 |
| 8 | 358 | 2 | 385 | 2 | 371 | 4 | - 2 |
| 9 | 345 | 7 | 364 | 8 | 355 | 15 | -16 |
| 10 | 390 | 5 | 383 | 17 | 385 | 22 | 29 |
| 11 | 411 | 6 | 422 | 20 | 419 | 26 | 34 |
| 12 | 377 | 7 | 404 | 22 | 398 | 29 | -21 |
| 13 | 365 | 7 | 424 | 15 | 405 | 22 | 7 |
| 14 | 401 | 6 | 413 | 15 | 409 | 21 | 4 |
| 15 | 364 | 5 | 479 | 6 | 427 | 11 | 18 |
| 16 | 411 | 3 | 424 | 2 | 416 | 5 | -11 |
| 17 | 410 | 2 | 405 | 1 | 408 | 3 | - 8 |
| 18 | 428 | 4 | - | - | 428 | 4 | 20 |
| 19 | 398 | 4 | - | - | 398 | 4 | -30 |
| 20 | 362 | 1 | - | - | 362 | 1 | -36 |
| 21 | - | - | 475 | 1 | 475 | 1 | 113 |
| 22 | 408 | 2 | | | 408 | 2 | -67 |
| 26 | 519 | 1 | | | 519 | 1 | |
| Total | | 72 | | 116 | | 188 | |

Table 6.–Dolly Varden mean lengths (mm) by age group, Tustumena Lake, Kenai National Wildlife Refuge, Alaska, 1987.

| | Male | | Female | | Immature | | Total | | |
|---|---|---|---|---|---|---|---|---|---|
| Age | Mean | N | Mean | N | Mean | N | Mean | N | Relative growth increment |
| 1 | | | | | 77 | 6 | 77 | 6 | |
| 2 | 140 | 1 | | | 104 | 45 | 105 | 46 | 28 |
| 3 | 239 | 1 | | | 123 | 26 | 128 | 27 | 23 |
| 4 | 261 | 7 | 289 | 5 | 150 | 24 | 191 | 36 | 63 |
| 5 | 307 | 38 | 313 | 48 | 258 | 7 | 306 | 93 | 115 |
| 6 | 343 | 31 | 368 | 48 | 360 | 1 | 358 | 80 | 52 |
| 7 | 403 | 25 | 372 | 24 | | | 388 | 49 | 30 |
| 8 | 415 | 15 | 380 | 25 | | | 393 | 40 | 5 |
| 9 | 376 | 6 | 397 | 10 | | | 389 | 16 | -4 |
| 10 | 449 | 1 | 428 | 4 | | | 432 | 5 | 43 |
| 11 | - | - | 379 | 9 | | | 379 | 9 | -53 |
| 12 | 422 | 1 | 449 | 2 | | | 440 | 3 | 61 |
| 13 | 372 | 1 | | | | | 372 | 1 | -68 |
| Total | | 127 | | 175 | | 109 | | 411 | |

For the 120 round whitefish aged (Table 7), ages ranged from 3 to 11 years. By age 7, 90% of the population was sexually mature. Ages 6, 7, and 8 were the most abundant. Back-calculation using scales gave an average annual growth rate of 27.0 mm per year with the growth slowing in older fish (Table 8).

## DISCUSSION

### *Relative Abundance*

Based on gill-net catch data, Dolly Varden was the most abundant resident fish species in Tustumena Lake, followed by lake trout and round whitefish. Species composition was very similar for all three locations sampled. However, Bear Creek consistently produced higher catches than Clear or Nikolai creeks. This could be attributed to higher productivity since Bear Creek is one of two sites where sockeye salmon fry are stocked each year as part of the Department's efforts to enhance Tustumena Lake. Adult sockeye salmon returning to Bear Creek to spawn and die contribute nutrients to the system. Other factors such as the availability of spawning and rearing habitat at each location also may be important factors influencing the differences in relative abundance between locations.

The dramatic increase in minnow trap catches in July is probably related to the large concentrations of sockeye salmon that spawn in these streams during this period. Dolly Varden, sculpins, and threespine sticklebacks are known to consume salmon eggs when available (Scott and Crossman 1973). The increased availability of salmon eggs could have concentrated otherwise more dispersed populations in these areas.

### *Food Habits*

Lake trout and Dolly Varden had very dissimilar food habits. Lake trout stomachs contained mostly fish and insects. Dolly Varden stomachs contained mostly insects and fish eggs. Although sockeye salmon fry were found in the stomachs of both lake trout and Dolly Varden, this was not a major item in the diet of either species. The Department stocked approximately one million sockeye salmon fry at the mouth of Bear Creek in June while our gill nets were set. Stomachs of most Dolly Varden and lake trout captured were completely full of sockeye salmon fry. It appears that these two species are at least opportunistic and readily take sockeye salmon fry when they are available. The increase in the percentage of stomachs containing food in June is probably related to increased food availability.

In an investigation to determine the degree to which lake trout and Dolly Varden prey on sockeye salmon fry in Tustumena Lake, Litchfield (1981) examined 58 Dolly Varden and 57 lake trout. Twenty-six percent of the Dolly Varden and 10% of the lake trout had sockeye salmon fry in their stomachs. Litchfield concluded that Dolly Varden use sockeye

TABLE 7.–Round whitefish mean lengths (mm) by age group, Tustumena Lake, Kenai National Wildlife Refuge, Alaska, 1987.

| | Male | | Female | | Immature | | Total | |
|---|---|---|---|---|---|---|---|---|
| Age | Mean | N | Mean | N | Mean | N | Mean | N |
| 3 | 215 | 1 | - | - | - | - | 215 | 1 |
| 4 | 244 | 2 | - | - | - | - | 244 | 2 |
| 5 | 260 | 1 | 257 | 5 | 242 | 1 | 255 | 7 |
| 6 | 266 | 9 | 261 | 13 | 261 | 4 | 263 | 26 |
| 7 | 277 | 12 | 277 | 26 | 249 | 4 | 274 | 42 |
| 8 | 282 | 11 | 287 | 16 | 269 | 3 | 283 | 30 |
| 9 | 343 | 2 | 278 | 4 | | | 299 | 6 |
| 10 | 310 | 2 | 325 | 2 | | | 317 | 4 |
| 11 | 284 | 1 | 310 | 1 | | | 297 | 2 |
| Total | | 41 | | 67 | | 12 | | 120 |

TABLE 8.—Back-calculated age and growth (mm) of round whitefish collected in Tustumena Lake, Kenai National Wildlife Refuge, Alaska, 1987.

| Year Class | N | Mean fish length (mm) | Age | Fork length at annulus formation | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 |
| 1983 | 2 | 244 | 4 | 47 | 139 | 205 | 244 | | | | | | | |
| 1982 | 6 | 247 | 5 | 54 | 111 | 172 | 211 | 247 | | | | | | |
| 1981 | 19 | 260 | 6 | 54 | 108 | 159 | 199 | 232 | 260 | | | | | |
| 1980 | 36 | 276 | 7 | 48 | 103 | 150 | 192 | 223 | 251 | 276 | | | | |
| 1979 | 25 | 284 | 8 | 48 | 99 | 142 | 177 | 208 | 237 | 261 | 284 | | | |
| 1978 | 5 | 305 | 9 | 32 | 81 | 121 | 167 | 206 | 233 | 261 | 286 | 305 | | |
| 1977 | 4 | 317 | 10 | 43 | 95 | 134 | 166 | 192 | 223 | 249 | 273 | 298 | 317 | |
| 1976 | 2 | 297 | 11 | 33 | 60 | 120 | 152 | 173 | 205 | 227 | 246 | 260 | 276 | 297 |
| Number of fish in each age | | | | 99 | 99 | 99 | 99 | 97 | 91 | 72 | 36 | 11 | 6 | 2 |
| Average fork length (mm) | | | | 48 | 102 | 149 | 189 | 219 | 246 | 267 | 281 | 294 | 303 | 297 |
| Average growth (mm) per year | | | | 48 | 54 | 47 | 39 | 31 | 27 | 21 | 14 | 13 | 9 | -6 |
| Average annual fish growth | | 27 mm/year | | | | | | | | | | | | |

salmon fry more frequently than lake trout but that the level of predation did not appear to be significant.

The food habits of lake trout and Dolly Varden in Tustumena Lake are quite similar to what investigators have found elsewhere. The most frequently occurring item in the stomachs of lake trout in most other Alaskan lakes is fish, especially in the larger lake trout (Roguski and Spetz 1968; Van Whye and Peck 1965; Engel 1971; Bendock 1979; Bendock and Burr 1985). However, the species is opportunistic and takes a variety of food items. Furniss (1974) found that lake trout in four lakes on the northern slope of the Brooks Range primarily had dipteran adults and larvae in their stomachs while fish occurred in the diet much less frequently.

In general, stream or lake-resident Dolly Varden in Alaska appear to consume aquatic insect larvae more than other food items (Armstrong and Morrow 1980), similar to Dolly Varden in Tustumena Lake. Chironomids, trichopterans, and ephemeropterans are the most frequently consumed insect prey. However, populations elsewhere are primarily piscivorous (Scott and Crossman 1973).

*Length-Weight Relationships and Relative Condition*

Age class separations were not discernable using length frequency histograms. Small length groups for both lake trout and round whitefish were absent from the catch. Failure to collect the smaller individuals of both species is probably more related to inadequate sampling of preferred habitat rather than gear selectivity, since gill nets captured Dolly Varden as small as 117 mm fork length.

The distinct bimodality of the Dolly Varden length frequency distribution is interesting. The most likely explanation for the failure to capture Dolly Varden between 170 and 220 mm fork length is gear bias. Although we successfully collected Dolly Varden as small as 117 mm fork length in our gill nets, the difference in mesh size between the panels with the two smallest mesh sizes (25-51 mm) might have been great enough that Dolly Varden between 170 and 220 mm fork length were not vulnerable to capture. We did not record our catches by mesh size, so the effectiveness of each panel in our gill nets cannot be evaluated.

Mature lake trout condition factors fluctuated over the range of all ages. The four oldest individual fish, ages 20, 21, 22, and 26, had condition factors ranging from 0.84 to 1.18. Van Oosten (1944) attributed lake trout growth variation within a lake to the tendency of that species to travel and feed alone, resulting in some individuals being more fortunate in finding adequate food (Redick 1967). This theory, more than age or sex-attributable differences, most likely explains the variation in condition observed in Tustumena Lake fish. Condition factors for lake trout in Tustumena Lake were comparable with those compiled by Martin and Olver (1980)(Appendix 1).

Very little information is available on the condition of Dolly Varden in other areas of Alaska. Heiser (1966) found anadromous Dolly Varden in southeast Alaska with condition factors of 1.02 to 1.18 for in-migrants and 0.79 to 0.86 for out-migrants at Eva Creek. Tustumena Lake Dolly Varden fall within this range.

*Age Structure and Growth Rates*

As growth slows in older fish, annuli are compressed and the ages become more difficult to determine. Therefore, otoliths were read at least three times. Barber and McFarlane (1987) found poor agreement in otolith ages between novice and experienced readers, with the novice readers tending to obtain lower ages. Our readers consulted frequently with Department readers in Soldotna and Homer and there appeared to be basic agreement in techniques and results.

Average growth increments for lake trout were variable. Some of this variability may be due to the small sample size of very young and very old fish, and difficulties in aging older fish, while some may be attributed to Van Oosten's (1944) theory that lake trout travel and feed alone, resulting in some individuals being more fortunate in finding food.

Data on lake trout growth from other glacial lakes in Alaska are not available for comparison with Tustumena Lake. However, compared to other lakes in Alaska, lake trout growth in Tustumena Lake is fairly typical (Appendix 2). Lake trout from Hidden Lake (a clearwater lake located approximately 40 km northwest of Tustumena Lake) were longer at most ages and the most prominent age groups were 7 to 10 (T. Bendock, Alaska Department of Fish and Game, personal communication). The majority of lake trout in Summit, Paxson, Fielding, and Seven Mile lakes were longer than Tustumena Lake fish at most ages (Burr 1987, 1988; Van Wyhe and Peck 1965). On the other hand, lake trout in Tangle, Twobit, and Glacier lakes generally were shorter than those in Tustumena Lake at most ages (Burr 1987, 1988). Generally, lake trout from areas outside Alaska had a faster growth rate than Alaskan lake trout (Martin and Olver 1980).

Of the Dolly Varden aged and sexed, females generally outnumbered males in all age groups for which an accurate sexing was possible. This may be a reflection of lower survival of males than females after spawning. Kruger (1981) found that males were less likely to survive spawning. Maximum growth occurred between age 4 and 5, when fish were becoming mature. Growth rate appears to peak at this time, then taper off with age. Ages ranged from 1 to 13, and at age 3 the population was 96% sexually immature. However, by age 5 only 8% were sexually immature.

Our data is comparable with that of other studies. In three southeastern Alaska streams, Armstrong (1974) found that more than 90% of the mature fish were ages 4-7 and more than 90% of the immature fish were ages 2-5. In Eva Creek, Baronof Island, Alaska, Heiser (1966) found that anadromous Dolly Varden were usually sexually mature by ages 5 or 6, a slower growth rate was exhibited by older fish, and the majority were from ages 3-5. However, Eva Creek Dolly Varden were consistently longer than those found in Tustumena Lake. Heiser also found large length variations in several age groups, which led to some older age groups with smaller mean sizes than younger age groups. He attributed this to an insufficient sample size in those age groups. This inconsistency also appeared in Tustumena Lake data.

Round whitefish in Tustumena Lake are similar to populations elsewhere in Alaska. Hale (1981) reported that round whitefish in Alaskan waters were usually less than 400 mm (fork length) and usually weighed less than 500 g, although specimens up to 520 mm and 1500 g have been taken. The longest round whitefish collected in Tustumena Lake was 375 mm fork length. According to Morrow (1980), sexual maturity is reached at about age 5 in the southern part of the Alaskan range but not until age 7 in the Brooks Range. In both Paxson and Summit lakes, Alaska, all round whitefish shorter than 220 mm total length and younger than age 4 were immature; whereas all fish longer than 290 mm and older than age 8 were mature (Van Whye and Peck 1965). In Tustumena Lake, 90% of the round whitefish sampled were sexually mature by age 7.

Direct assessment of the impact of sockeye salmon enhancement on resident fish in Tustumena Lake is not possible at this time. However, data collected during this investigation strongly indicates that such enhancement activities might be responsible for increased productivity at the site of enhancement. Consistently higher gill-net catches of resident fish at Bear Creek, as opposed to Clear Creek and Nikolai Creek, may indicate higher productivity. However, whether this is due to natural conditions in Bear Creek or to ongoing enhancement of sockeye salmon was not determined.

ACKNOWLEDGEMENTS

We would like to express our appreciation to Terry Bendock, Jeff Breakfield, and John Burr of the Alaska Department of Fish and Game for providing assistance and information on lake trout aging. Special thanks are extended to Max Pease and Perry Flotre of the Peninsula Dental Laboratory, Soldotna, Alaska, for providing their laboratory space and equipment for otolith preparation. We would also like to thank co-workers Jeff Booth, Mary Wunderlich Faurot, and Gerry Gray; and Student Conservation Association volunteers Tim Edgar, R.D. Nelle, Ted Otis, and Brad Weinischke. Finally, we want to thank our secretary Anne Barrett for typing the report.

## REFERENCES


Ambrose, J. 1983. Age determination. Pages 301-324 *in* L.A. Nielsen and D.L. Johnson, editors. Fisheries techniques. American Fisheries Society, Bethesda, Maryland.

Anderson, R.O. and S.J. Gutreuter. 1983. Length, weight, and associated structural indices. Pages 283-300 *in* L.A. Nielsen and D.L. Johnson, editors. Fisheries techniques. American Fisheries Society, Bethesda, Maryland.

Armstrong, R.H. 1974. Migration of anadromous Dolly Varden *Salvelinus malma* in southeastern Alaska. Journal of the Fisheries Research Board of Canada 31: 435-444.

Armstrong, R.H. and J.E. Morrow. 1980. The Dolly Varden charr, *Salvelinus malma*. Pages 99-140 *in* E.K. Balon, editor. Charrs. Dr. W. Junk, The Hague, Netherlands.

Barber, W.E. and G.A. McFarlane. 1987. Evaluation of three techniques to age Arctic char from Alaskan and Canadian waters. Transactions of the American Fisheries Society 116: 874-881.

Barnes, R.D. 1974. Invertebrate Zoology. 3rd Edition. W.B. Saunders, Co., Philadelphia, Pennsylvania.

Bendock, T. 1979. Inventory and cataloging of Arctic area waters. Alaska Department of Fish and Game. Federal Aid in Fish Restoration, Annual Progress Report, 1978-1979, Project Number E-9-11, Juneau, Alaska.

Bendock, T. and J. Burr. 1985. Inventory and cataloging, Arctic and Western Alaska. Alaska Department of Fish and Game. Federal Aid in Fish Restoration, Annual Progress Report, 1983-1984, Project Number F-9-16, Juneau, Alaska.

Burr, J. 1987. Stock assessment and biological characteristics of lake trout populations in interior Alaska, 1986. Alaska Department of Fish and Game, Fishery Data Series Number 35, Juneau, Alaska.

Burr, J. 1988. Stock assessment and biological characteristics of lake trout populations in interior Alaska, 1987. Alaska Department of Fish and Game, Fishery Data Series Number 66, Juneau, Alaska.

Engel, L.J. 1971. Evaluation of sport fish stocking on the Kenai Peninsula-Cook Inlet areas. Alaska Department of Fish and Game. Federal Aid in Fish Restoration, Annual Progress Report, 1970-1971, Project Number F-9-2, Anchorage, Alaska.

Flagg, L.B., K.E. Tarbox, D.C. Waite, and J.L. Dean. 1986. Sockeye salmon investigations, Tustumena Lake system, Alaska. Alaska Department of Fish and Game, Upper Cook Inlet Data Report Number 86-3, Soldotna, Alaska.

Furniss, R.A. 1974. Inventory and cataloging of arctic area waters. Alaska Department of Fish and Game. Federal Aid in Fish Restoration, Annual Progress Report, 1973-1974, Project Number F-9-6, Anchorage, Alaska.

Hale, S.S. 1981. Freshwater habitat relationships, round whitefish *Prosopium cylindraceum*. Alaska Department of Fish and Game, Habitat Division, Anchorage, Alaska.

Heiser, D. 1966. Age and growth of anadromous Dolly Varden char *Salvelinus malma* (Walbaum) in Eva Creek, Baronof Island, southeastern Alaska. Alaska Department of Fish and Game. Research Report Number 5, Juneau, Alaska.

Kruger, S. 1981. Freshwater habitat relationships, Dolly Varden char *Salvelinus malma* (Walbaum). Alaska Department of Fish and Game, Habitat Division, Anchorage, Alaska.

Lagler, K.F. 1956. Freshwater Fishery Biology. Wm. C. Brown Company, Dubuque, Iowa.

Litchfield, D. 1981. Investigations of juvenile sockeye salmon and productivity parameters in Tustumena Lake, 1980. Alaska Department of Fish and Game, Juneau, Alaska.

Martin, N.V. and C.H. Olver. 1980. The lake charr, *Salvelinus namaycush*. Pages 205-277 *in* E.K. Balon, editor. Charrs. Dr. W. Junk, The Hague, Netherlands.

Merritt, R.W. and K.W. Cummins, editors. 1978. An introduction to the aquatic insects of North America. Kendall/Hunt Publishing Co., Dubuque, Iowa.

Morrow, J.E. 1980. The freshwater fishes of Alaska. Alaska Northwest Publishing Company, Anchorage, Alaska.

Pennak, R.W. 1978. Freshwater invertebrates of the United States, 2nd Edition. John Wiley and Sons, New York, New York.

Redick, R. 1967. A review of lake trout life history with notes on Alaskan management. Alaska Department of Fish and Game, Information Leaflet III, Homer, Alaska.

Ricker, W.E. 1975. Computation and interpretation of biological statistics of fish populations. Fisheries Research Board of Canada, Bulletin 191, Ottawa, Canada.

Roguski, E.A. and C.E. Spetz. 1968. Inventory and cataloging of the sport fish and sport fish waters in the interior of Alaska. Alaska Department of Fish and Game. Federal Aid in Fish Restoration, Annual Progress Report, 1967-1968, Project Number F-5-R-9, Anchorage, Alaska.

Scott, W.B. and E.J. Crossman. 1973. Freshwater fishes of Canada. Fisheries Research Board of Canada, Bulletin 184, Ottawa, Canada.

Van Oosten, J. 1944. Lake trout. U.S. Fish and Wildlife Service, Fisheries Leaflet 15: 1-5.

Van Whye, G.L. and J.W. Peck. 1965. A limnological survey of Paxson and Summit Lakes in interior Alaska. Alaska Department of Fish and Game. Federal Aid to Fish Restoration, Annual Progress Report, 1962-1964, Project F-5-R-3, Fairbanks, Alaska.

Windell, J.T. and S.H. Bowen. 1978. Methods for study of fish diets based on analysis of stomach contents. Pages 219-226, *in* T. Bagenal, editor. Methods for the assessment of fish production in fresh waters. Blackwell Scientific Publications, Oxford, England.

APPENDIX 1.-Lengths and condition factors for lake trout from selected stocks (Martin and Olver 1980).

| Lake | N | Size range (cm) | Condition factor (K) range | Condition factor (K) mean |
|---|---|---|---|---|
| Tustumena Lake, AK[a] | | | | |
| mature | 172 | 27.5 - 56.0 | 0.71-1.45 | 1.01 |
| Kaminuriak, NWT | 352 | 22.4 - 100.5 | 0.89-1.54 | 1.23 |
| Hottah, NWT | 538 | 18.7 - 103.3 | 0.89-1.46 | |
| Waterton, Alberta | 248 | 19.3 - 92.7 | 0.87-1.55 | 1.19 |
| Big Trout, Ontario | 1238 | 12.7 - 101.3 | 0.72-1.19 | 0.96 |
| N. Caribou, Ontario | 28 | 33.0 - 101.3 | 0.69-1.25 | 1.05 |
| Sutton, Ontario | 285 | 25.4 - 101.3 | 0.69-1.47 | 0.89 |
| Hawley, Ontario | 1076 | 25.4 - 88.6 | 0.69-1.02 | 0.80 |
| Deer, Ontario | 171 | 25.4 - 101.3 | 0.83-1.36 | 0.97 |
| Mistassini, Quebec | 603 | 18.0 - 102.0 | 0.90-1.57 | |
| Lake Superior | | | | |
| lake charr | 221 | 61.0 - 91.2 | 0.78-1.10 | 0.91 |
| Lake Michigan | 11228 | 16.5 - 88.6 | 1.15-1.65 | 1.25 |
| Michigan Hatchery | 1370 | 20.3 - 30.5 | | 0.84 |
| Green, Wisconsin | | | | |
| immature | 119 | 15.2 - 58.2 | 1.05-1.56 | 1.26 |
| mature | 483 | 63.5 - 114.0 | 1.56-2.28 | 1.90 |
| Minnesota lakes | | | | 1.43 |
| Opeongo, Ontario | | | | |
| 1937-1947 | 2050 | 31.8 - 64.8 | | |
| 1953-1965 | 5085 | 31.8 - 64.8 | | |
| L'Assomption, Quebec | | | | |
| immature | 134 | | | 0.75 |
| Tremblant, Quebec | | | | |
| adults | | | | 1.01 |
| Quabbin Res, MA | 1045 | | 0.44-1.58 | |
| Odell, OR | 478 | 19.6 - 100.3 | 0.96-2.40 | 1.27 |
| Tahoe, CA-NV | 2416 | 7.6 - 87.6 | | |
| Pearson, New Zealand | 2509 | 7.6 - 87.6 | 0.87-1.36 | 1.23 |

[a] Data collected during this investigation. Condition factor was calculated as Kn.

Appendix 2.–Mean length at age of lake trout in selected stocks (Martin and Olver 1980).

| Location | Length at age (cm) | | | | | | | | | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 | 16 | 17 | 18 | 19 | 20 | 21 | 22 | 23 | 24 | 25 | 26 |
| Great Bear L., NWT | | | | | | | 38 | 39 | 27 | 50 | 41 | 51 | 49 | 55 | 57 | 60 | 58 | 59 | 63 | 63 | 64 | 65 | 65 | 70 | 70 | |
| Great Slave L., NWT | | | | | 41 | 37 | 48 | 49 | 49 | 51 | 54 | 55 | 56 | 56 | 59 | 60 | 61 | 63 | 63 | 62 | 65 | 68 | 53 | 60 | 57 | |
| Kaminuriak L., NWT | | | | | | 22 | 29 | 28 | 27 | 33 | 37 | 39 | 43 | 48 | 50 | | 54 | 55 | 55 | 56 | 56 | 58 | 62 | 58 | 60 | |
| U. Waterton L., Alta. | | | 25 | 33 | 37 | 42 | 51 | 55 | 71 | 83 | | | | | | | | | | | | | | | | |
| L. Waterton L., Alta | | | | 42 | 49 | 53 | 59 | 65 | 73 | 82 | 86 | 85 | 90 | 88 | | | | | | | | | | | | |
| Lac la Ronge, Sask. | | 27 | 38 | 43 | 51 | 54 | 59 | 61 | 64 | 66 | 69 | 71 | 75 | 79 | 81 | 83 | 89 | 92 | | | | | | | | |
| Reindeer L., Sask. | | 20 | 25 | 30 | 35 | 39 | 42 | 44 | 47 | 50 | 52 | 55 | 57 | 59 | 62 | 65 | | | | | | | | | | |
| L. Mistassini, Que. | | | 21 | 23 | 32 | 36 | 41 | 43 | 48 | 49 | 51 | 54 | 53 | 53 | 53 | 54 | 52 | 57 | 58 | 52 | 60 | 59 | 62 | 56 | | |
| L. Mistassini, Que. | | | 21 | 23 | 34 | 40 | 47 | 52 | 56 | 62 | 72 | 80 | | | | | | | | | | | | | | |
| B. Trout L., Ont. | | 23 | 29 | 38 | 49 | 53 | 53 | 58 | 58 | 62 | 67 | 72 | 91 | 95 | 96 | 99 | | | | | | | | | | |
| South Bay, Ont. | | 25 | 30 | 42 | 48 | 52 | 58 | | | | | | | | | | | | | | | | | | | |
| L. Simcoe, Ont. | | | | | 55 | 62 | 66 | 71 | 76 | 78 | 79 | 80 | 80 | 80 | 80 | | | | | | | | | | | |
| L. Louisa, Ont. | 10 | 18 | 20 | 24 | 33 | 34 | 37 | 40 | 44 | 52 | 51 | 55 | | | | | | | | | | | | | | |
| L. Opeongo, Ont. | | | | | | | | | | | | | | | | | | | | | | | | | | |
| 1937-1949 | | 26 | 29 | 34 | 37 | 41 | 45 | 49 | 51 | 56 | 60 | 66 | 70 | 71 | 75 | | | | | | | | | | | |
| 1955-1961 | | 20 | 24 | 28 | 34 | 37 | 44 | 50 | 55 | 58 | 62 | 66 | 70 | 72 | 75 | 86 | | | | | | | | | | |
| C. Stream Pond, Me. | | | | 42 | 44 | 49 | 52 | 58 | 61 | | | | | | | | | | | | | | | | | |
| Moosehead L., Me. | | | | 28 | 37 | 41 | 47 | 54 | 57 | | | | | | | | | | | | | | | | | |
| Cayuga L., N.Y. | 16 | 24 | 33 | 44 | 53 | 59 | 63 | 66 | | | | | | | | | | | | | | | | | | |
| Newfound, N.H. | | | 42 | 46 | 50 | 58 | 66 | 73 | 77 | | | | | | | | | | | | | | | | | |
| Quabbin R. Mass. | | | | | | | | | | | | | | | | | | | | | | | | | | |
| 1967 | 12 | 25 | 36 | 43 | 53 | 55 | 63 | 68 | 73 | | | | | | | | | | | | | | | | | |
| 1970 | 20 | 33 | 42 | 49 | 54 | 60 | 64 | 71 | 74 | 76 | | | | | | | | | | | | | | | | |
| Odell L., Oreg. | | 28 | 32 | 31 | 38 | 43 | 62 | 66 | 66 | 79 | 81 | 90 | 91 | | 100 | | | | | | | | | | | |
| L. Tahoe, CA-NV | 12 | 18 | 25 | 32 | 38 | 43 | 48 | 53 | 58 | 62 | 67 | 70 | 72 | 77 | 82 | 85 | 91 | | | | | | | | | |
| Fish L., Utah | 14 | 21 | 30 | 38 | 44 | 51 | 59 | 69 | 77 | 82 | 81 | 83 | 87 | | | | | | | | | | | | | |
| Fish L., Utah | 19 | 29 | 37 | 43 | 49 | 54 | 62 | 70 | 75 | 80 | 83 | 84 | 87 | | | | | | | | | | | | | |

Appendix 2.—(Continued).

| Location | Length at age (cm) | | | | | | | | | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 | 16 | 17 | 18 | 19 | 20 | 21 | 22 | 23 | 24 | 25 | 26 |
| Lake Superior | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Lake charr | 10 | 16 | 22 | 29 | 36 | 43 | 52 | 60 | 69 | 78 | 87 | | | | | | | | | | | | | | | |
| Humper | 9 | 13 | 18 | 22 | 26 | 33 | 39 | 45 | 50 | 56 | 62 | | | | | | | | | | | | | | | |
| Montreal R. | | | | | | 63 | 71 | 79 | 82 | 84 | 85 | | | | | | | | | | | | | | | |
| Lake Michigan | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Northern | 18 | 25 | 33 | 41 | 48 | 55 | 61 | 67 | 73 | | | | | | | | | | | | | | | | | |
| Southern | 14 | 22 | 31 | 39 | 47 | 53 | 59 | 64 | | | | | | | | | | | | | | | | | | |
| Georgian Bay, | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Lake Huron | | 22 | 29 | 33 | 42 | 49 | 54 | 58 | 64 | 64 | 85 | | | | 114 | | | | | | | | | | | |
| S. Bay, L. Huron | | 25 | 32 | 42 | 48 | 52 | 58 | 79 | 74 | | | | | | | | | | | | | | | | | |
| Tustumena[a] | | | | 31 | 33 | 33 | 37 | 37 | 36 | 39 | 42 | 40 | 41 | 41 | 43 | 42 | 41 | 43 | 40 | 36 | 48 | 41 | | | | 52 |
| Paxson[b] | 6 | 12 | 18 | 24 | 29 | 36 | 43 | 49 | 51 | 59 | 63 | 74 | 78 | | | | | | | | | | | | | |
| Paxson[c] | | | | 37 | 41 | 45 | 52 | 53 | 52 | 61 | 57 | 58 | 64 | 69 | 57 | 57 | 56 | 58 | 60 | 61 | 53 | - | 60 | 76 | - | |
| Summit[b] | 6 | 10 | 16 | 21 | 27 | 32 | 37 | 41 | 46 | 49 | 55 | 61 | 71 | 81 | | | | | | | | | | | | |
| Summit[e] | 12 | 14 | 27 | 29 | 35 | 43 | 46 | 50 | 50 | 51 | 51 | 55 | 48 | 49 | 52 | 57 | 55 | 60 | 53 | 57 | - | 49 | 51 | 50 | 87 | |
| Hidden Lake[d] | | | | 24 | 30 | 32 | 37 | 38 | 42 | 44 | 46 | 47 | 48 | 50 | 49 | 50 | 51 | 51 | 45 | 50 | | 49 | | | | |
| Fielding Lake[e] | | | | 31 | 35 | 41 | 44 | 48 | 54 | 48 | 65 | - | 70 | | | | | | | | | | | | | |
| Tangle Lake[e] | 16 | - | - | - | - | 27 | 29 | 31 | 32 | 33 | 34 | 34 | 38 | 40 | 40 | 41 | 40 | 39 | 41 | 41 | 42 | 42 | 44 | - | 42 | 43 |
| Twobit Lake[c] | - | - | - | - | 24 | 26 | 28 | 31 | 32 | 35 | 37 | 38 | 38 | 40 | 38 | 40 | 43 | 41 | 41 | 42 | 41 | 41 | 44 | - | 38 | 41 |
| Glacier Lake[c] | 13 | 16 | 20 | 26 | 27 | 30 | 33 | 35 | 36 | 39 | 41 | 41 | 45 | 42 | 44 | 44 | 43 | 46 | 43 | 41 | - | 43 | 43 | - | - | 43 |
| Seven Mile Lake[c] | 14 | 21 | 35 | 32 | 38 | - | 41 | 42 | 41 | 42 | 43 | 46 | 44 | 45 | | | | | | | | | | | | |

[a] Data collected during this investigation
[b] Van Wyhe and Peck 1965
[c] Burr 1987
[d] Bendock, Alaska Department of Fish and Game, personal communication
[e] Burr 1988